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WORK OF THE MISSISSIPPI RIVER COMMISSION

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I recommend that the thesis prepared under my supervision by WILLIAM GEORGE SCHOCH entitled Work of the Mississippi River Commission be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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INTRODUCTION

In this thesis, it has been the purpose of the author to give a brief but comprehensive study of the work of the Mississippi River Commission, which has been completed,and that now under construction. Together with this, the author has endeavored to give a short history of the Commission from its inception to the present day, taking up all its salient features which proved to be influential in its life, special attention being given to the bill that formed the Commission. In addition to this, the author has endeavored to give the methods of improving the river and a brief summary of the actual work accomplished with a table giving the amount and dates of the appropriations made by Congress. In conclusion, the author has endeavored to summarize the work, to state the benefits derived from improving the river, and to give the opinion of the Commission in regard to the practicability and desirability of constructing and maintaining a deeper and wider channel than is now in use.

DESCRIPTION OF THE MISSISSIPPI RIVER.

The Mississippi River lies almost unused in the most rapidly developing traffic region in the continent. It rises in the northern part of Minnesota and flows almost due southward, emptying into the Gulf of Mexico. No other river system in the world offers such natural facilities for internal and external trade, as does the Mississippi and its branches.

The basin of the river consists of nearly all the land in the United States between the Rocky and Alleghany Mountains, and has an area of one million two hundred and forty-four thousand (1,244,000) square miles. For the purpose of traffic and engineering development, the river may be divided into six principal streams or collections; the main river below St. Louis, the Ohio, the Chicago-Illinois route to the lakes, the Upper Mississippi, the Missouri, and the minor tributaries. The last includes, by a free use of the term, the Tennessee, the Cumberland, the Arkansas, and the Red River. The six divisions comprise at least eighteen thousand (18,000) miles of channel susceptible of development to a navigable stage, not including the allied waters to which they are connected. There has been no accurate estimate, but it is certain that more than sixteen thousand (16,000) miles have actually been traversed by steam-boats and have been taken in charge by federal engineers.

The major channels, which constitute what is called the "trunk line system" of the Mississippi, and upon which traffic of the center is waiting, may be represented graphically as in Fig. 1. This shows the general trend of the system and the depth in each stream. A fourteen foot water-way in the main river below St. Louis and in the Chicago-Illinois route to the lakes; a six foot channel in the Missouri River and the Upper Mississippi; and a depth of nine feet in the Ohio River.

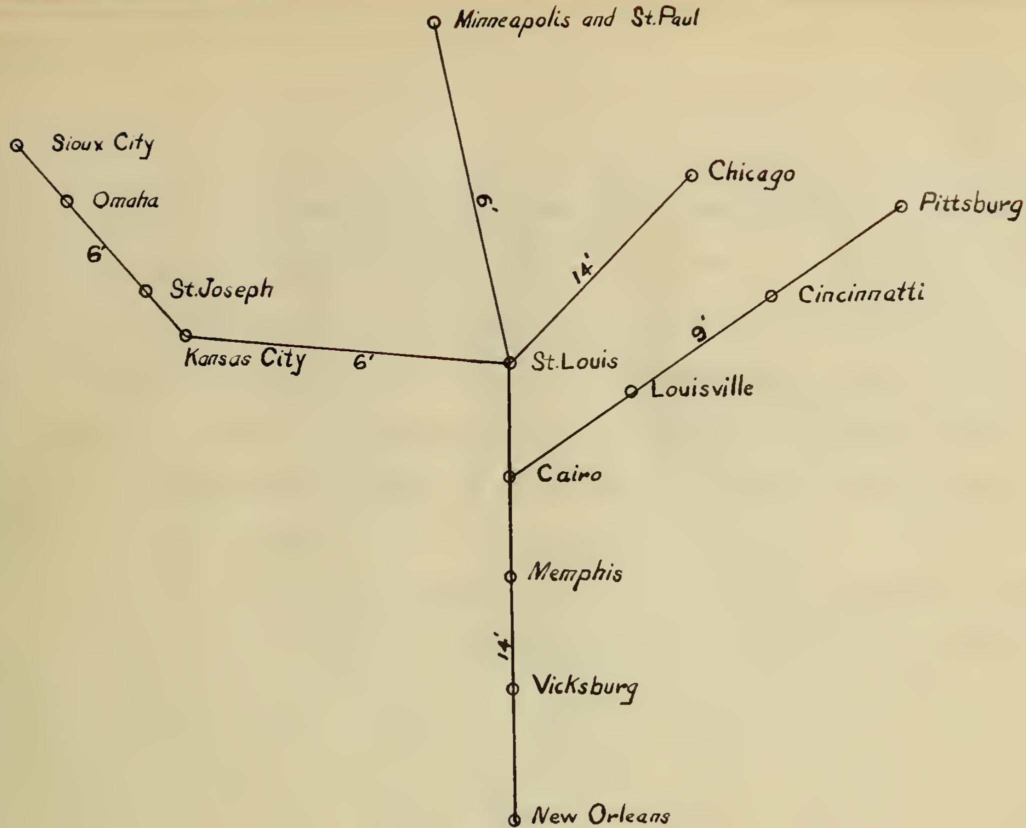

Fig.1

No better plan for economy in construction and operation could have been designed than this system for carrying the products of the interior to the seaboard. At the head of the Ohio is Pittsburg, one of the greatest manufacturing centers in the world. Immense shipments of pig and manufactured iron, steel in all shapes, glassware, and manufactured articles of many other kinds originate in this city and the regions surrounding it. These must be carried not only to the seaboard but to the distributing centers at St. Louis and other cities on the Mississippi. Pittsburg is the natural outlet for the product of the Pennsylvania and West Virginia coal mines, from which millions of tons are shipped annually to New Orleans and intermediate points. Great sugar refineries, in which the syrups of Louisiana are transformed, and factories and yards which require millions of feet of southern lumber are situated in this region.

At the end of the Illinois route, where the rivers and lakes unite, stands Chicago, the greatest railway center in the world. Here, at the head of Lake Michigan, are gathered all those raw materials, sand, iron ore, coal, wood, fibre, and pulp which make possible the establishment of a large manufacturing center. The corn and wheat of the west are gathered at Chicago for

forwarding and for transmutation into numerous by-products. Countless tons of meat products, of iron and steel goods, of harvesters and reapers, of furniture, of clothing and of cereal foods are required to be borne to the seaboard and other distant points of distribution from this place. Here, too, are collected by great lake ships all the tribute of the cities about the Lakes, to be exchanged for southern goods or to be sent on down the river to the Gulf, and then abroad.

At the head of the Upper Mississippi, where the great river plunges over fall after fall to generate eventually more than two hundred thousand electric horse-power, have been established the collecting and distributing centers of the North, St. Paul and Minneapolis. More than half of our wheat flour is produced at these places. These cities have the trade of the Northwest and the fast developing Canadian cities. Deposits of iron ore are found along the river which could be transported down stream and smelted by the cheap and abundant coal of Illinois and Missouri.

Farther west still, the Missouri plunges down over the Great Falls with a force of five hundred thousand(500,000) horse-power. From here it finds its way across the Bad Lands of North Dakota, where irrigation from it is working a miracle; and passes by Sioux City, Omaha, and Kansas City, which are the great depots of corn and wheat.

This upper system, in its present condition, is not capable of furnishing a means of transportation for the many products of its basin. The channels are obstructed by shifting bars and altered by moving banks; they are from time to time blocked by snags; they are interrupted by periods of low water and by floods which obliterate landmarks.

The Mississippi River starts at Lake Itasca and wanders back and forth thru the swamps in a very tortuous manner for about two hundred miles to Pokegama Falls. The entire drainage area is low and swampy, containing many small lakes. The higher portions are densely wooded, while the lower regions consist of large reed fields and quaking bogs. The soil is generally sandy with clay cropping out at many places. The remainder of the river to the

mouth of the Missouri flows through a well defined valley with bluffs on either side, rising at places to a height of four hundred feet. It wanders back and forth through the valley from bluff to bluff, the channel at no place holding close to either bank for any considerable distance. From Pokegama Falls to the Falls of St. Anthony the valley is quite narrow. There are numerous rapids in this portion and a number of islands just above the Falls of St. Anthony. The bed and banks of the river are very stable, changing but little under the erosive influence of the water.

From the Falls of St. Anthony to Rock Island the valley is somewhat broader. At Fulton, Illinois, the bluffs disappear and the banks above the bottom lands rise gently to the level of the Illinois and Iowa prairies. The general features of the river are much the same as above the Falls of St. Anthony. The bluffs are composed of magnesium limestone inter-stratified with soft sandstone. The different rates of abrasion of the strata have caused considerable local variations in the appearance of the bluffs, and the rock terraces of different elevations have been formed. The terraces of sand and gravel are found at the foot of the bluffs. At Rock Island there are about fourteen miles of rapids over a bed of rocks. Similar rapids exist at Des Moines. From the mouth of the Illinois River to the Missouri River the banks are alluvial, being composed of the sediment deposited by the river water in times of flood. Then the river overflows the bottom lands to depths of from six to twelve feet, obscuring all channel marks. The channel does not suffer much change owing to the stable character of the bed. Great quantities of sand are brought down from the terraces during floods, traveling down stream and being deposited in the form of bars across the channel.

The rest of the river from the Missouri to the mouth flows through a great alluvial plain. It winds in a most tortuous manner. The banks are torn down at one place and built up at another. The cutting action of the current is confined mostly to the apices of the bends. This tends to lengthen the river, and consequently reduces the slope of the bed and the velocity

of the current. The bends overlap each other, however, and the neck of the land separating them is soon worn away from both sides until it is too narrow to withstand the pressure of the water and a cut-off is formed. These cut-offs shorten the river and increase the velocity of the current. The regimen of the river above and below is affected and the scour in the bends is accelerated, causing the river to lengthen rapidly and resume its normal conditions.

The bottom lands average about forty miles in width and have an area of about thirty-two thousand (32,000) square miles. For the first mile the lateral slope toward the river is approximately seven feet. After the first mile the fall is about six inches per mile.

This whole area is subject to over-flow during high water, rendering more than ten million (10,000,000) acres of the richest land practically worthless. The rapid changes of the channel prohibit the location of permanent works close to the river. Entire farms are swept away by a single flood.

Navigation is seriously impeded by high water. Sand waves are started down stream and new sand bars are formed. During the falling stage the water becomes sur-charged with sediment from the caving banks, and wherever the current reduced silt is deposited. The water becomes comparatively shallow over the sand bars and silt deposits until channels are cut through them by the concentration of the current.

These shallows make navigation difficult to all boats other than those of a light draft. When the river is at its lowest stage even the use of these is impracticable. The dredging of these shallows forms one of the most important parts of the work of the engineers who are now in charge. This method is, however, only a temporary means of relief as the sand fills the channel again in a short time. The construction of permanent works, such as, revetments, wing-dams, and other structures will be necessary in order to make the proposed traffic possible at all times.

It was for this purpose that the Mississippi River Commission was formed.

HISTORY OF THE COMMISSION.

Ever since April 30, 1803, when the United States bought the Mississippi River, or rather the Louisiana Territory, which included the river, there has been much interest in regard to improving the great stream. In the earlier days, much of this was done by the states bordering on the river. Conventions composed of representatives from the different states were held, at which plans and projects for development and retention of the channel were discussed.

The first convention assembled in July, 1845 at Memphis, six states being represented. After organizing and doing a certain amount of business, it adjourned until the following November. On its re-assembling in that month twelve states were represented by some five hundred delegates. Two years later a convention was held in Chicago, followed by another at Burlington, Iowa in 1851. In 1866 five hundred men, part of whom were legislators of Iowa, assembled at Dubuque for the purpose of considering the improvement of the Upper and Lower Rapids. Many other conventions were held as follows, at Keokuk in 1867; at New Orleans in 1869, 1875, 1876, 1879, and 1880; at St. Louis in 1872, and 1873; Vicksburg in 1875; St. Paul in 1878; at Quincy in 1879; and at Davenport in 1881.

A large convention was held at St. Louis, October 26, 1881. The idea of this convention originated with the commercial bodies of St. Louis. They asked the governor of each state in the Mississippi Valley to appoint ten men, territories only being allowed five each. Each board of trade or cotton exchange sent two delegates for each one hundred members. From corporate cities where no board of trade or exchange existed, two delegates were appointed by the mayor. The President and Vice President of the United States, members of the Cabinet, Senators and Representatives in Congress, and Governors of the States and Territories were invited to the convention. The valley included eighteen states and three territories. The improvement of the Mississippi River was no longer an affair of the states that bordered on the river but of the United States.

Two years previous to this last convention, there was introduced in Congress a bill for the appointment of a Mississippi River Commission. The bill, except an amendment for increasing the number of members from five to seven became a law June 28, 1879 and is as follows:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That a commission is hereby created, to be called "The Mississippi River Commission", to consist of seven members.

Sec. 2. The President of the United States shall, by and with the advice and consent of the Senate, appoint seven commissioners, three of whom shall be selected from the Engineer Corps of the Army, one from Coast and Geodetic Survey, and three from civil life, two of whom shall be civil engineers. And any vacancy which may occur in the Commission shall in like manner be filled by the President of the United States; and he shall designate one of the commissioners appointed from the Engineer Corps of the Army to be president of the Commission. The commissioners appointed from the Engineer Corps of the Army and the Coast and Geodetic Survey shall receive no other pay or compensation than is now allowed them by law, and the other three commissioners shall receive as pay and compensation for their services each the sum of $3,000.00 per annum, and the commissioners appointed under this act shall remain in office subject to removal by the President of the United States.

Sec. 3. It shall be the duty of said Commission to direct and complete such surveys of said river, between the Head of the Passes, near its mouth, to its headwaters as may now be in progress, and to make such additional surveys, examinations, and investigations, topographical, hydrographical, and hydrometrical, of said river and its tributaries, as may be deemed necessary by said Commission to carry out the objects of this act. And to enable said Commission to complete such survey, examinations, and investigations. The Secretary of War shall, when requested by said Commission, detail from the Engineer Corps of the Army such officers and men as may be necessary, and shall place in charge and for the use of said Commission such vessel or ves-

sels and such machinery and instruments as may be under his control and may be deemed necessary. And the Secretary of the Treasury shall, when requested by said Commission, in like manner detail from the Coast and Geodetic Survey such officers and men as may be necessary, and shall place in charge and for the use of said Commission such vessel or vessels and such machinery and instruments as may be under his control and may be deemed necessary. And said Commission may, with the approval of the Secretary of War, employ such additional force and assistants, and provide, by purchase or otherwise, such vessels or boats and such instruments, and means as may be deemed necessary.

Sec. 4. It shall be the duty of the Commission to take into consideration and mature such plan or plans and estimates as will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River; improve and give safety and ease to navigation thereof; prevent destructive floods; promote and facilitate trade, commerce, and postal service; and when so prepared and matured, to submit to the Secretary of War a full and detailed report of their proceedings and actions, and of such plans, with estimates of cost thereof for the purposes aforesaid, to be by him transmitted to Congress: Provided, That the Commission shall report in full upon the practicability, feasibility and probable cost of the various plans known as the jetty system, the levee system, and the outlet system, as well as upon others as they deem necessary.

Sec. 5. The said Commission may, prior to the completion of all the surveys and examinations contemplated by this act, prepare and submit to the Secretary of War plans, specifications, and estimates of costs for such immediate works as in the judgment of said Commission may constitute a part of the general system of works herein contemplated, to be by him transmitted to Congress.

Sec. 6. The Secretary of War may detail from the Engineer Corps of the Army of the United States an officer to act as secretary of said Commission.

Sec. 7. The Secretary of War is hereby authorized to expend the sum of $175,000, or as much thereof as may be necessary, for the payment of the salaries herein provided for, and of necessary expenses incurred in the completion of such surveys as may now be in progress, and of such additional surveys, examinations, and investigations as may be deemed necessary, reporting the plans and estimates, and the plans and specifications, and estimates contemplated by this act, as herein provided for; and said sum is hereby appropriated for said purposes out of any money in the Treasury not otherwise appropriated."

The Commission met for organization in the city of Washington, August 19, 1879, all members being present. Immediately after organizing, it took into consideration the surveys of the river already "in progress" and "such additional surveys", "examinations", and "investigations", "topographical", "hydrographical", and "hydrometrical", as deemed necessary to carry out the objects of the act of Congress. It was found that the portion of the river lying above the mouth of the Ohio had been essentially covered by the several shore-line surveys already completed. Therefore, the attention of the Commission was directed especially to the lower river between Cairo and the Head of the Passes. This portion measuring one thousand one hundred (1,100) miles along the channel, had been covered by numerous detached surveys. The data from these was available, notwithstanding the intervals of time that had passed. In providing for the extension of these, the Commission decided to so arrange the work that the information immediately required should be obtained by systematic methods, useful, not only for their immediate needs, but in future years.

It was considered important that the triangulation so essential in locating the river, however limited the field of practical operations of immediate improvement might be, should be executed and permanently marked so that it would furnish the basis of future surveys. It was decided that a line of secondary triangulation should be run, its triangles closing within six seconds. It was deemed not desirable to execute any detailed or widely ex-

tended topography, but to develop as rapidly as possible the shore lines and the forms of the river bed.

It was furthermore decided that physical inquiries, extending to all the recognized phenomena likely to have bearing upon the problems of improvement, should be commenced at once, and that they should be based upon the experience of predecessors who had already made much progress in these studies. Provisions were made for running lines of precise levels along the river bank and for maintaining and increasing the number of stations at which the elevations of the river were recorded, so as to be able to trace in future the progress of floods, and the larger features of the river slope, and to be able to carry on physical examinations of selected reaches some distance apart, but presenting locally and relatively the most widely contrasted elements of width, depth, and curvature, so that conditions most favorable and inimical might thus be traced back to their causes inductively.

On February 17, 1880, the Commission made a preliminary report in which various plans of improvement were discussed. One of these plans was approved by an act of Congress March 3, 1881. This plan was to limit the width of the shoal portions of the river to three thousand (3,000) feet and to protect caving banks where necessary. This narrowing and limiting of the low water was to be effected if possible by constructions of a much lighter and cheaper character than those heretofore used, if after thorough experiment, such should be found effecient; if not, then as a last resort, by the ordinary dikes, used in such work in this country and Europe, made of brush, or stone and gravel.

The portion of the river above the mouth of the Ohio River had been covered by several shore line surveys. Thus the attention of the Commission could be directed more especially to that portion of the river below Cairo. Numerous detached surveys had been made on this section, but none that could be relied upon. The Commission continued working on this part of the river as directed by Congress until August 2, 1882, when the River and Harbor Bill became a law. This act put the actual work in charge of the Engineering Department of the Army, under the general supervision of the Commission, and

placed the Commission in charge of the work at Memphis Harbor, Vicksburg Harbor, Natchez Harbor, rectification of the Red and Atchafalaya Rivers, and New Orleans Harbor. The work at these places had previously been carried on by special appropriations. This act also extended the territory under the supervision of the Commission to include the Mississippi River between the mouths of the Des Moines and the Illinois Rivers and between the mouths of the Illinois and Ohio Rivers which work had been for several years under the direction of the United States Army.

Upon the recommendation of the Commission the lower portion of the river was divided into four districts. The first, extended from Cairo to the foot of Island Number 14, two hundred twenty miles in length; the second, from the foot of Island Number 14 to the mouth of the White River, one hundred eighty miles in length; the third, from the mouth of the White River to Warrenton, Mississippi, two hundred twenty miles in length; and the fourth from Warrenton to the Head of the Passes, four hundred eighty four miles in length. An officer of the Corps of Engineers of the United States Army was put in charge of each district.

Not much work could be done by the Commission from December 1, 1884 until August 11, 1888 because the necessary appropriations were lacking. At a meeting of the Commission which lasted from June 30 to July 2, 1887, previous allotments that had not been approved were canceled, and the greater portion of the sum devoted to them re-alloted to levee construction, leaving such amounts as were thought necessary for care of plant, office expenses, surveys and protection of existing works.

An appropriation was made by Congress on August 11, 1888. At the same time Congress ordered a large number of detached works. Up to this time the work of the Commission had been largely confined to a few special reaches where navigation was unusually difficult and where the feasibility of the work could be thoroughly tested and its value to the country estimated. These improvements were not finished, but had proved so satisfactory that the need of many others along the river could be readily seen.

On September 19, 1890 Congress passed the River and Harbor Bill which provided for the improving of the Mississippi River from the mouth of the Ohio River to the Head of the Passes. All traveling, clerical, office, and miscellaneous expenses of the Commission were included in the bill. All operations which had been suspended for want of means were resumed as soon as practicable after the appropriation of this act was available.

Between September 19, 1890 and June 3, 1896, the Commission continued as directed. During that time, many meetings were held and several trips were made by it from St. Louis to the Head of the Passes for the purpose of inspecting the work.

In accordance with the act of Congress approved June 3, 1896, a modified project was adopted for obtaining and maintaining by means of hydraulic dredges a channel in the Mississippi River below Cairo. This channel was to be two hundred fifty feet wide and nine feet deep, and was to be kept open throughout the year, except when the ice made this impracticable. Many new dredges were ordered and the efficiency of each determined by the Commission.

On March 3, 1899, the Mississippi River Commission was ordered by Congress by the River and Harbor Bill to examine the harbor at Memphis, Tennessee, and report what improvement, if any, should be made to remove the bar of sand in front of the city of Memphis, together with the cost thereof. To comply with this provision of the law, the Commission made a special examination of the harbor, and after giving the subject of its maintenance and improvement careful consideration, reported their conclusions in their annual report of June 30, 1899.

On June 13, 1902, a River and Harbor Act was approved by Congress, which provided a board of five men to make a survey, with plans and estimates of cost, for a navigable waterway fourteen feet deep from Lockport, Illinois, by way of the Mississippi River to St. Louis, Missouri; and for a navigable waterway of seven and eight feet deep, respectively, from the head of navigation of the Illinois River at La Salle, Illinois through the said river to Ottawa, Illinois. This bill contained an item that directed the Commission

to make such surveys, examinations, and investigations as might be required to determine the feasibility of a fourteen foot waterway from St. Louis to the mouth of the Illinois River. The Commission was to prepare and report plans and estimates of the cost of this navigable waterway.

On March 2, 1907, the River and Harbor Act was approved by Congress. By this act five men, three of whom were members of the Mississippi River Commission, were appointed by the Secretary of War. This committee was to investigate the feasibility of a fourteen foot channel from St. Louis to the Head of the Passes. This is the last act which altered the work of the Commission. The Mississippi River Commission is still in existance and is performing its work, as directed by Congress, diligently at the present time.

CLASSIFICATION AND DISCUSSION OF THE WORK.

The work of the Commission can be divided into four parts; surveying or field work, levee building, revetment building or bank protection, and dredging.

FIELD WORK: This takes up, secondary triangulation, precise levels, topography and hydrography, regular gage inspections, and discharge observations*

The objects of the survey of the Mississippi River are, to obtain sufficient data for an accurate topographical and hydrographical map which may be used in studying the physical characteristics of the river, planning improvements, and also serve as a basis of future surveys by means of which the changes in bed and banks may be ascertained and their causes and effects studied. The work is done as accurately as possible.

In order to keep in close touch with the condition of the improvement works, the caving banks, and changes affecting the regimen of the river, annual surveys are made covering such portions of the river as may be required.

*Instructions for performing this work can be obtained, in pamphlet form, by writing to the Mississippi River Commission, St. Louis, Missouri.

Two of the important things to be noted in the instructions for secondary triangulation are that the smallest angle in any triangle should never be less than 30 degrees and that the error in closing a triangle should rarely reach and never exceed six seconds. Very few 30 degree triangles should be permitted in a system.

LEVEE BUILDING: Levees are artificial embankments constructed along the bank of a stream to confine the flood discharge and protect the bottom lands from overflow.

The first levee along the Mississippi River was built by De la Tour in 1717. It was to protect the city of New Orleans and was about one mile long. Many levees have been built since that time and much improvement has been made in their construction.

In constructing a levee, it has been found that the location is a very important part of the work. If located too near the river, it is liable to be undermined by the water and destroyed. On the other hand, if it is located so far from the bank as to render it safe from undermining, a great deal of the most valuable land is left without protection. This land soon becomes covered with cotton wood and thick under-brush, rendering it almost useless for discharging flood waters.

Next to the location in importance is the clearing of the ground of its trees, stumps, logs, trash, weeds, and all perishable matter. After all these things have been removed, the entire surface of the ground must be thoroughly broken with a spade or plow. Then, a muck ditch must be cut on the river side of the center line; all stumps and roots crossing it being carefully taken out and removed beyond the base of the levee; the muck ditch is then filled in with buckshot earth ot clay, obtained from without the base of the levee, which is tamped in by horses or mules, driven back and forth constantly while the clay is being put in, or by tamping mauls, at least one horse to every ten wheelbarrow, or one tamping maul to every six wheelbarrows. This filling and tamping is kept one quarter of a mile in advance of the embankment. When the chief constituent of the levee is sand, or other porous material, a

wall of buckshot earth or clay, five feet thick, is required to be continued from the muck ditch to the top of the levee, the earth being tamped in by horses in the same manner as the muck ditch, as the levee is being built on each side. The object of this is to obtain a stratum through the levee impervious to percolating water. If the chief constituent of the levee is stiff buckshot or clay, a wall of sand eight feet thick is required to be continued from the surface of the muck ditch to the high water mark, as the levee is built up on each side of it. The object of this being to obtain a stratum through the levee impervious to crayfish.

After the ground has been prepared, the embankment is commenced; the slopes being started full out to the side stakes and carried up regularly. The embankment must be built one-fifth higher than the grade height marked on the stakes, to allow for shrinkage or settling. Material is to be obtained from places designated by the engineer. At intervals of one hundred feet berms must be left across the borrow pits to prevent the flow of a current along the levee. All earth for embankment must be entirely devastated of roots, trash, and other perishable matter before being put in place.

The grade of the levee is three feet above the greatest flood. The slopes on both sides are 3:1 with a width at the top of about eight or ten feet. A banquette is placed at the back of the levee as shown in Fig. 2.

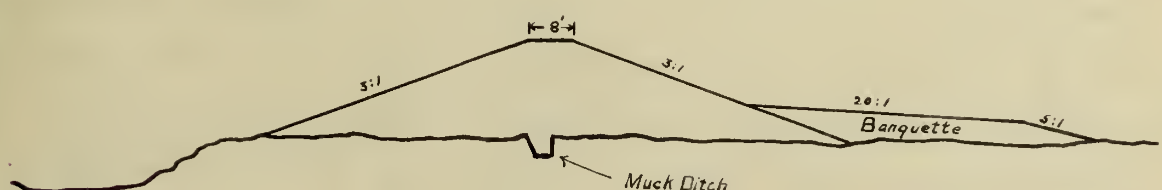

Fig. 2

Where considered necessary a double course of sheet piling, breaking joints, are driven at the center or on either side of the levee five feet below the surface of the ground, and extending up to within six inches of grade. The plank used must be of heart red gum, white oak, or cypress, and of specific dimensions. All piling is driven in advance of the levee, and the embankment constructed on both sides of the piling simultaneously. A breakwater of post and plank is constructed where necessary on the river slope of the levee properly braced and filled in behind with earth. In anticipation of destructive floods during the progress of the work, a protection of timber work is built around the ends of the levee, and a temporary protection levee in front of the work.

In case of repair of old levees, all stumps, logs, and trees, where they are known to exist, must be dug out and a muck ditch dug near the outside base of the old levee, if thought necessary by the engineer. The surface of all old levees must be well broken before new material is added.

REVETMENT BUILDING: A revetment is a mattress placed in the river channel near the bank to keep the water from washing away the earth which forms the border line of the channel of the stream.

Before 1879, when Congress appointed the Commission, the Government works on the Mississippi River were not revetment works proper. These works were more to control and rectify the channel, or to close chutes, and consisted chiefly of piles, dikes, and training walls. The policy was to force all the water of the river into one main channel.

The first continuous revetment work was done in 1879. It was only a protection of the banks under low water. It was anticipated that the bank above low water would not need to be protected and would take care of itself.

This revetment consisted of a mattress one hundred fifty feet long and fifty feet wide, built on ways erected on a barge. These ways had inclined skids or runs six feet beyond the edge of the barge. The mattress was composed of a longitudinal bottom crib or layer, made of poles six inches in diameter at the butt, secured by wire and spikes eight inches apart to a cross-set of

stringers of the same dimensions. All intersections of this crib were provided with vertical pins of hickory, one inch in diameter and three inches long. This bottom crib or layer was covered by five layers of small willow brush, each layer being placed at right angles to the one above and below, and of a total thickness of two feet. On top of these layers of brush was set a top crib similar to the bottom one in construction and dimensions, secured to pins by wedges, nails, and wire. The mattress completed, ropes were fastened to it in such a manner as to be freed by toggles when at the bottom. Then, the mattress was launched from the ways and towed to the site of the bank to be protected. When in position, rock was thrown from barges to sink it in place. Such a mattress protected one hundred fifty feet of subaqueous slope.

It was found in 1880 that the upper slope exposed to the current action was needing protection. For this reason the bank was then graded to a slope of 45 degrees and covered by a mat eight inches thick, fastened to the ground by wire tied to "dead men". It was expected that this upper-slope mattress would soon be covered by sediment, during high stages of the river.

This method of mat construction was entirely modified in 1881. The poles, crib frames at top and bottom and the hickory pins were replaced by wire netting fastened by wire stitches passing through the mat. Under the netting logitudinal poles were placed eight feet apart to assist in launching and on top cross rows of piles were wired to the mat. These poles formed pockets, preventing the ballast rocks from rolling off during the sinking.

The mattress on the slope above low water, was also loaded down with rip-rap rock. During that year the slope grading was done by means of a hydraulic jet for the first time.

The next year, 1882, the mattress construction underwent other changes. The type of mattress adopted was what is known as "woven mattress". These mattresses were built in continuous lengths of from three hundred to two thousand feet. For this method of construction the entire plant had to be altered. A mooring barge one hundred seventy feet long and twenty-six feet wide was placed, end on the bank, at the upper end of the bend to be revetted.

This barge was secured in position by manila ropes leading to "dead men" on shore or to anchors in the stream. To this mooring barge, on its down-stream side, the floating ways were secured by one inch rope. The mattress was built on the floating ways and composed of a layer of thirty foot willow poles, lapping from four to six feet, fastened together with number twelve wire and six inch spikes, and placed across the runs near their large ends resting on the transverse system, and the whole was tightly wired and secured together. These constituted the weaving poles. On top of these a set of poles similar to the first was laid transversely, wired and spiked. This formed a mat-head. Willow brush was then woven over and under the longitudinal poles, the brush being about thirty feet long and from three to four inches at the butt. Each woven line of brush extending the whole length of the floating ways was tightly fitted to the mat-head and to the preceding one by means of mauls.

This weaving process was continued until the thirty feet of poles were filled with woven brush. Space enough was left to spike and wire other poles. Every thirty feet of mattress completed was launched. For this the lines holding the mooring barge were slackened and the ways dropped down stream under the mat. When the length required to protect the bank was built, the sinking took place. After the mattress was sunk, it was secured in place by piles driven through its near-shore edge. The upper slope bank was then graded and revetted with willow mattresses placed diagonally between two frames of poles ten to twelve feet apart, well secured together by number eight wire and spikes. When the upper bank revetment did not overlap the subaqueous mat, a connecting mattress was built overlapping both shore, and river revetment. The shore mat was covered with rock in quantity sufficient to destroy its bouyancy.

From 1883 to 1893 this method of revetment was improved at nearly every working season, but in the main the construction was the same. The manila rope fastenings were replaced by cables. The plant, mooring barge and floating ways were changed and altered to follow the different modifica-

tions in the construction. In 1890 this method of "woven mattress" was perfected as far as such construction could be. But it was found that this mattress was not flexible enough to adjust itself to the irregular bottom of the river which led to the undermining of the revetment by the water.

For this reason the Mississippi River Commission decided to adopt some kind of fascine mattress which would be stronger and more flexible. The width was also to be increased. From 1890 to 1892 several experiments were made with fascine mattresses. As the results of these experiments it was finally decided to adopt the fascine mattress as bank revetment. The materials and plant used are, with slight modifications, the same as before. The mattress barges or floating ways were provided, underneath the platform, with a number of cable drums, one under each inclined way, on which was wound and from which was payed out, as the construction of the work progressed, the steel wire strand which constituted the longitudinal strength of the mat, and to which the fascines were attached or more properly woven. The distance between drums was eight or nine feet. On top of the platform fascine forms were placed. The main difference of construction between the early type of mattress and the fascine mattress was the replacing of the bottom and top crib poles by a net of wire strands, so the flexibility would be increased.

The first operation of the mattress proper is building the mat-head. This consists of a bundle two and one-half to three feet in diameter, made of poles five to eight feet in length, well bound together be a wire strand and forming a beam of great length of some regidity, but having also a great flexibility. This mat-head is as long as the mattress is wide and is moored to the bank by steel wire cables independent of the mooring barge. The number of cables used depends upon the width of the mattress and the strength of the current. The wire strands which are one-quarter inch steel are also attached to the mat-head, one for each longitudinal strand upon which the fascines are woven. The brush is carried from a brush barge to the former and is placed in two layers with tops in opposite directions and the joints broken. Enough brush is put in to make a fascine ten to twelve inches in

diameter. It is then choked at every run, and bound into fascines by number twelve steel wire. This fascine, having the length of the mat, is raised from the formers and skidded on runs to its position next to the mat-head.

The weaving strand is then passed over the fascine, down underneath it, and up between the fascine and mat-head, crossing at the same time the bottom longitudinal strand. It is then put into a "paron clamp" and drawn taunt by means of double block and tackle, the men pulling upstream against the fascine already in place. The strand is temporarily stapled to a pole of the mat-head. The second fascine being in place, the weaving strand is passed over the first and second fascines down underneath the second and up between the first and second, at the same time crossing the bottom longitudinal strand as before by block and tackle and temporarily stapled to a piece of brush in the first fascine. The weaving and bottom strands are clamped together by a cable clamp every ten feet (diagonally) and at points intermediate between the clamps both strands are stapled to the brush to prevent the fascines from separating during the process of weaving.

On top of the mattresses thus constructed are placed rows of poles, sixteen feet apart, extending up and down stream. They are lashed to the fascines by number seven silicon bronze wire every five feet and at intermediate points by strong steel wire lashings. These poles are to prevent the stone from slipping off the mat when it is sunk on a steep slope, and also by being lashed to the body of the mattress by non-corrosive wire to prevent the displacement of the brush after the steel wire weaving strand and other corrosive connections shall have rusted away.

When the ways are filled the mattress is launched in the usual way and the construction proceeded with. The brush composing the fascines does not exceed three inches in diameter. One-half and five-sixteenth inch strands of wire are used for the bottom longitudinal strands, the one-half inch size being used at the channel edge of the mat, where the current is greatest, and the five-sixteenth inch nearer shore; one-quarter inch strand is used exclusively for weaving.

The sinking is done as follows: The mattress is first ballasted nearly

to the sinking point with rock delivered directly from barges by wheel-barrows on run plank the usual way. The "mat-head" held up to the mooring barge by the "slip lines", is ballasted to its full load and then lowered enough to let the rock barge in and out. These barges are lashed end to end and swung from the mooring barge by parallel two-inch manila ropes, long enough to pay out over the whole length of the mattress. After the first fifty feet of mattress is heavily ballasted the "slip lines" are loosened slowly and continuously until the mattress head is on the bottom of the river and all "slip lines" slack. This operation consumes a few minutes of time. Particular care is taken to have the mattress head sink to the bottom without delay, so that the friction of the mattress on the bottom will aid the mooring cables in holding the mattress and to avoid the heavier strain which would result from a submerged mattress waving in the current free from the bottom, a strain which may cause the loss of a mattress. The rock barges are then dropped down over the mattress and the rock is thrown over evenly and continuously.

With the mattress of the early type the sinking sometimes required two days. With the fascine mattress, in thirty minutes after the rock barges are across the head of the mat, the sinking is completed.

Connection mattresses, overlapping the shore and the subaqueous mattresses are built by the same method.

The slope above low water is not now covered by mattress, as in the early method, but after the grading is done the slope is paved with four to six inches of spalls, overlaid by six inches of stone, extending up the bank to about the twenty foot stage. Sometimes concrete is used in place of stone.

During the experimental stage of the work grading of slope banks was done with shovels, then with sluice boxing and hydraulic jet. It is now done entirely by the hydraulic process.

The hydraulic grade used consists of a barge carrying a pumping plant discharging two thousand gallons per minute under a pressure of one hundred ten pounds per square inch, through four inch hose to nozzle, the pressure at the nozzles being about one hundred twenty-five pounds per square

inch. The grading is done after the mattress is sunk. The material washed from the bank fills the inequalities of the ground which may exist at the shore end of the subaqueous mattress.

The material used per aquare (one hundred square feet) is approximately as follows: brush, 1.5 cords; poles, 0.08 cords; stone, 0.75 cubic yards; wire, galvanized, No. 12, 3 pounds; wire strand, galvanized, 1/4 inch, 6 pounds; wire strand, galvanized, 5/16 inch, 4 pounds; wire strand, galvanized 1/2 inch, 1 pound; bronze silicon wire, 2 pounds; clamps 5/16 inch, 1.35 in number; and clamps 1/2 inch, 0.16 in number. The total cost per lineal foot of bank is about $30.00.

SUBMERGED SPURS: Submerged spurs are long narrow cribs placed at right angles to the bank, at intervals of about five hundred feet. The interval, however, depends upon the angle with which the current strikes the bank. The spurs are broad at the bottom and taper to the top. They are high enough to obstruct materially the flow of the water over them and thus prevent scour and even induce deposits.

They are constructed of the same material and in much the same manner as the submerged part of the revetment.

DIKES: Much improvement of low water navigation has been accomplished by contracting the channel over the sand bars and by closing chutes with permeable dikes and training walls. The former are perpendicular or inclined at an abrupt angle to the course of the river and the latter are parallel or nearly so to it.

Permeable dikes allow the water to flow through them, offering however, considerable resistance, which causes a reduction of the velocity and consequently a deposition of the suspended material. By a combination of a number of such dikes, systematically arranged, it is the thought that artificial banks, equal in height to natural banks, may be produced. Training walls are used in conjunction with dikes to prevent the formation of eddies.

The dikes consist of two or more rows of piles, and a willow mattress at the bottom to prevent scour. Sometimes a brush screen is added. The rows

of piles are from eight to twenty-five feet apart and the spacing in the rows from seven and one-half to eight feet.

The willow mattress is first sunk into position and the piles driven through it. A number of anchor piles are driven in the river about one hundred and fifty feet up stream. To these the first row of piles in the dike are secured as soon as driven. The successive rows are fastened together by cables and braces as shown in Fig. 3.

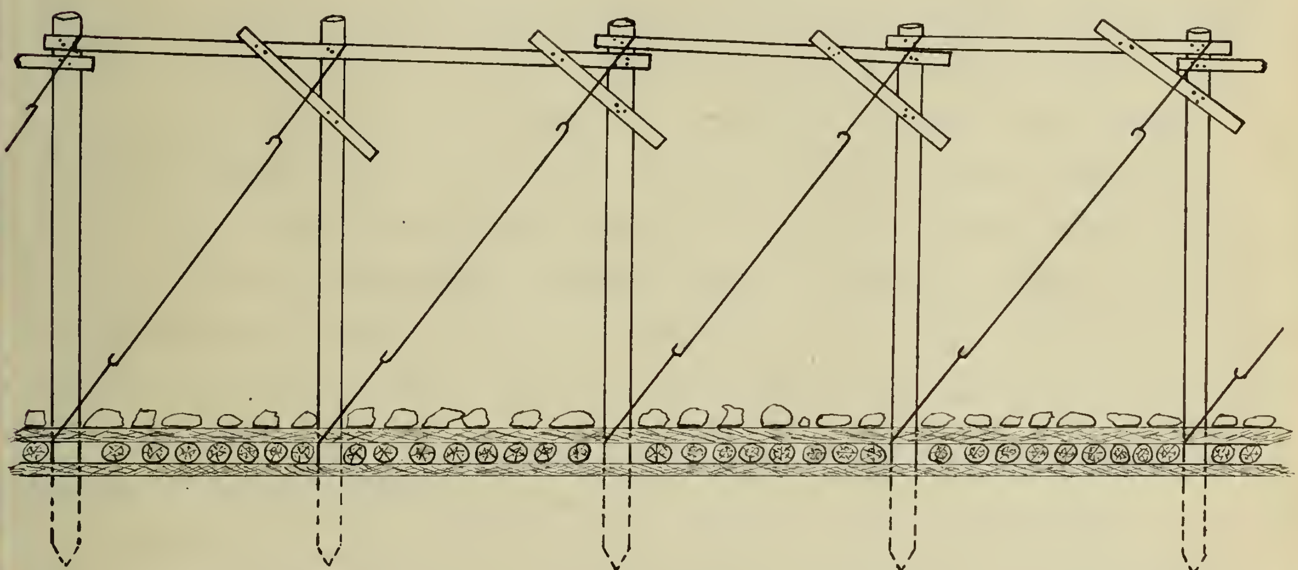

Fig.3

The brush screen consists of willows wound tightly to a light wooden frame. After the completion of the dike, the anchor piles are either pulled up or sawed off below the surface of the water.

DREDGES: The forward-feeding type of hydraulic dredge which is adapted for shallow work in alluvial rivers is sometimes called the Mississippi type, because it has received its greatest development on this river.

In 1892, the subject of dredging as an available method of improving the

Mississippi River, by removing the sand bars which made navigation difficult, was taken up by the Commission but at that time the feasibility of such a method when applied to such a vast river was greatly doubted. It was decided to construct an experimental dredge. Realizing that any one of the dredges then in use was too small, plans were drawn for a dredge which would have four times the capacity of those then in use and resulted in the building of the dredge, Alpha. Preliminary tests of the Alpha were made in 1893, and the first effort made to improve navigation in 1894. This dredge although imperfect in many ways, demonstrated its ability to make a passage through a bar at low water with sufficient effectiveness to afford temporary relief for the passage of steamers, and upon the experience thus gained the requirements for succeeding dredges were formulated. In 1894, the Mississippi River Commission issued these requirements with invitation for competitive designs and proposals to furnish a dredge of large capacity. Out of a number of designs submitted, three were finally selected and ordered built with the avowed object of putting them to the test and ascertaining their respective merits. These three were constructed and named, Beta, Delta and Gamma, respectively. These were followed by the Epsilon, Zeta, Iota, Kappa and Henry Fladd. The Beta, at the time of her construction, was the cause of considerable interest to the Engineering Profession, as at that time she was the largest dredge in the world.

The Alpha was operated until 1898, but owing to the facts that she could dredge only to a depth of twelve and one-half feet, that her capacity was comparatively small, and that her hull was of wood, she was dismantled in 1901.

The Beta stands in a class by herself, owing to her size and to the fact that she has two independent pumps and operating engines. Many radical changes have been made in the original design.

The five dredges, Beta(as rebuilt) Gamma, Epsilon, Delta and Zeta have general characteristics which are very similar. They have steel hulls, rectangular in plan and cross-section, from one hundred thirty-eight to two hundred fourteen feet long, from thirty-eight to fifty-eight feed wide, and about seven

feet deep. At the bow the hull is recessed for a depth, fore and aft, of about thirty to thirty-five feet. This recess has a slightly greater width than suction head, and forms a well protecting the head and within which it is raised and lowered.

The sand pumps are located near the bow and are driven by direct-connected, modern high-speed, compound or triple expansion engines. All the pumps except that on the Delta, have double suction or intake pipes leading forward to the bow bulkhead where they are joined to the pipes contained in the suction head by hinged, telescopic joints. The suction head is of such length as to permit of dredging to a depth of eighteen feet on the Epsilon and Zeta, twenty feet on the Gamma and Delta, and thirty-six feet on the Beta. The under side of the suction heads, at their forward or outer ends, have nozzles from two and one-half to three and one-half feet apart, pointing forward. These nozzles have an inside diameter of from one to two and one-half inches; and are supplied with water under pressure by either centrifugal or reciprocating pumps. Each dredge, near the bow, has an oak spud, twenty-two inches square, for the purpose of holding the dredge in position while attaching, hauling cables to the mooring piles, or while changing the position of the piles.

On the deck near the bow there are two powerful hauling engines which handle cables attached to piles and by which the dredge is hauled over the bar which is being dredged. There are also hoisting engines for handling the suction and the speed.

The discharge pipe leads from the pump along the bottom of the hull to the stern of the dredge then to the floating discharge pipe. This pipe is built in sections of about fifty feet, though the Beta has some one hundred feet sections. The pipe is supported by pontoons, formed either of circular closed pipe attached to each side of the discharge pipe by yokes, or by oval shaped buoyancy chambers, partially surrounding the pipe and riveted to it. The sections of the pipe are connected by rubber joints about three and one-half feet long, which allow a certain amount of deflection between adjoining sections. The rubber joint is relieved of any pulling strain by draw-bars between each section.

The boilers are near the aft-end of the dredge. In addition to the foregoing machinery there is the necessary equipment of condensers, feed pumps, capstans, electric light plant, and a complete machine and blacksmith shop.

The second, or cabin, deck has comfortable and commodious quarters for a double crew.

The Iota, Kappa and Henry Flad differ from the former principally in the fact that they are self-propelling and are larger and more powerful machines. Many details in design which have been found weak in the operation of the older dredges have been corrected in the latter ones.

THE SAND PUMP: The most important feature of a hydraulic dredge is the main sand pump. The different types used vary widely as to form and dimensions, so that each had to be tested for capacity, velocity of discharge and efficiency. To make these tests, the Commission fitted up a barge to attach to the lower end of the discharge pipe, and by suitable valves the discharge could be led either overboard or into the barge, at will. This barge was one hundred seven and one-half feet long, twenty-four feet wide, and six and one-half feet deep, and provided with suitable wells and valves for drawing off the water without disturbing the sand deposited therein. The necessary gauges for determining the height of the sand and water were also provided and very ingenious valve whereby the discharge could be deflected almost instantaneously. Precautions were taken to prevent leakage and to insure that all the discharge emptied into the barge would be measured.

In making a test, the dredge pumps were started, the suction head lowered into the sand, and the dredge pulled ahead as in actual work, the barge-valve being set to discharge into the river. When everything was running smoothly and at a preconcerted signal, the barge-valve was thrown to discharge into the barge and at the same time a stop-watch started. When all the material that the barge would safely hold had been discharged, the barge-valve was thrown to discharge into the river, the stop-watch being stopped at the same time. During the time the material was being pumped into the barge, indicator cards were taken on the engines, the suction head and discharge head at the pump were noted

and the steam pressure and number of revolutions of the engines were taken and recorded.

After a few minutes' time, to allow the agitated water in the barge to settle the gauges were read, showing the total height of material pumped; this height multiplied by the known area giving the total volume pumped. The water was then drawn off leaving the sand to be measured; this was done by measuring the depth at eleven points on each of eleven cross-sections. The average depth multiplied by the known area gave the volume of sand. Samples of sand from each test were dried and weighed carefully and the percentage of voids obtained.

The suction pressure was measured by a piezometer inserted in the suction pipe and connected with a manometer filled with mercury. The discharge head or pressure was measured by a piezometer inserted in the discharge pipe near the pump and connected to a manometer, filled in some instances with water and in others where the head was large, with mercury. All pressures were reduced to feet of water and to the centers of the pipes.

THE CAPACITY AND EFFICIENCY OF EACH DREDGE

Name	Capacity in cu. yds. per hour	Efficiency of pump and engine	Efficiency of pump
Alpha	7,400	66	68
Beta	16,000	43	48
Delta	14,400	56	60
Gamma	12,400	66	71
Kappa	13,600	69	74
Epsilon	15,800	72	78
Zeta	12,200	70	77
Iota	15,600	68	73
Henry Flad	13,200	71	77

On April 25, 1906, contract was entered into for the construction of a new dredge of greater capacity than any previously built by the Commission, to be named B. M. Harrod. This dredge was completed on July 5, 1907. After the Government tests had been made and certain adjustments and alterations by the contractor, the dredge was finally accepted on May 8, 1908. This dredge was much more efficient and of much greater capacity than any of those previously built. The capacity is 40,000 cubic yards per hour.

ACTUUAL WORK DONE BY THE COMMISSION

SURVEYING: A total survey of the Mississippi River from the Head of the Passes to the headwaters and several re-surveys at special places have been made by the Mississippi River Commission.

MAPS: Several maps and charts have been published by the Commission as follows: A map of the lower alluvial valley of the river, from the vicinity of Cairo to the Gulf of Mexico, in eight sheets; a map of the valley of the river from Cairo to St. Paul, in four sheets; and a district map from Cairo to the Gulf, showing improvement and levee districts, in one sheet. All the above maps are drawn up with the scale one inch to five miles. Detail charts, scale 1:20000, together with an index and title sheets have been completed. These charts show the hydrography of the river and the topography of the territory near the river from the Gulf to Minneapolis, Minnesota, a distance of one thousand nine hundred fifty-seven (1,957) miles. Detail charts, scale 1:10000, similar to the above showing the river from Minneapolis to the source of the Mississippi, are in progress of compilation. Forty-one sheets have been published, extending this series two miles below Split Head Creek, one thousand one hundred eighty-six (1,186) miles above Cairo. Maps of the Mississippi River, scale one inch to one mile, from the Gulf of Mexico to one and one-half miles above Grand Rapids, Minnesota, one thousand two hundred sixteen (1,216) miles above Cairo, in seventy-six sheets with index, title page and cover have been published. This series is being extended toward the source of the river. A map of New Orleans, in four sheets, scale 1:10000, showing Fort Chalmette, similar to the one of detail charts described above; and also a map of Lake Itasca, in colors, scale 1:15000 in one sheet have been published. St. Francis Basin, scale one-half inch to one mile, in two sheets has been drawn up by the Commission.

LEVEES: Both banks of the portion of the river below Cairo are almost a continuous line of levees. By far the greater part of these have been built by local authorities. Many of them were constructed before the forming of the Commission and many have been built by them since then. Restrictions, as special appropriations, kept the Commission from building many levees until 1890 when

this work formed one of the most important items in the operations of the Commission.

At present there are more than one thousand five hundred (1,500) miles of levees, or more than seventy-two percent of the number of miles needed for a perfect system from Cairo to the Head of the Passes. The contents is about two hundred thirty-five million (235,000,000) cubic yards. About two-fifths of the total number of levees have been built by the Commission. Many repairs which are very frequent have been made by it and many of the levees have been protected from destruction by mattresses.

REVETMENTS AND OTHER WORKS: Channel Work, Bank Protection and Harbor Improvements in the Several Districts.

First district: The construction works for channel improvement, protection of caving banks, and harbor work in this district are located at Columbus and Hickman, Kentucky, New Madrid and Caruthersville, Missouri, and Plum Point reach together with certain isolated works consisting of low-water channel dikes at different points throughout this district.

The work at Columbus, twenty-one miles below Cairo, consists of five submerged dikes, protecting two thousand two hundred (2,200) feet of harbor front. At Hickman, thirty-six miles below Cairo, one thousand four hundred fifty (1,450) feet of effective continuous revetment has been placed to prevent caving along the lower portion of the town. Slight repairs have been made on this revetment, extending along the river front of the town four thousand four hundred fifty (4,450) feet. This revetment consists of a continuous fascine mattress two hundred sixty feet wide with rip-rap paving on the graded bank above low water. At Caruthersville, one hundred ten miles below Cairo, one spur dike and a continuous revetment for the protection of the caving bank in front of the town two thousand four hundred (2,400) feet long have been constructed. The works at Plum Point Reach one hundred forty-seven to one hundred eighty-six miles below Cairo, comprise about sixty-seven thousand four hundred (67,400) feet of revetment for the protection of caving banks, the partial closure of the chutes behind Elmot bar and Island Number Thirty with a brush and stone dam, the closure of Osceola and Bullerton chutes with pile dikes, and a levee along

the left bank to confine the flood waters more nearly to the low-water channel.

Abatis dikes which are used for the purpose of closing secondary chutes and for contracting the low-water channel by building up sand bars have been used at Cherokee Crossing and at Ashport bar.

Second district: This district includes the protection of caving banks and harbor work at Hopefield Bend, Helena, Old Town and Walnut Band, Arkansas, and Memphis, Tennessee.

A revetment sixteen thousand six hundred (16,600) feet long has been constructed at Hopefield Bend, two hundred twenty-seven miles below Cairo. At Walnut Bend, two hundred eighty-one miles below Cairo, two dikes nine hundred seventy(970) feet apart have been built. The upper dike is one thousand four hundred fifty-four (1,454) feet long and the lower dike one thousand seven hundred fifty-five (1,755) feet long. A revetment about three thousand eight hundred (3,800) feet long has been built at this point to protect a levee along the bank. The revetment work at Helena, three hundred eight miles below Cairo, consists of the protection of four thousand nine hundred (4,900) linear feet of river bank in front of the city, of which three thousand five hundred (3,500) feet is continuous revetment and one thousand four hundred (1,400) feet is dike work. At Old Town, three hundred twenty-four miles below Cairo, two abatis dikes were constructed in the upper part of the bend in front of the city one thousand three hundred seventy (1,370) feet apart. The upper dike is nine hundred (900) feet long and the lower one, one thousand two hundred sixty (1,260) feet long. Five thousand one hundred fifty (5,150) feet of revetment has been built at this point and the bank paved to a suitable height. The effective length of revetment along the Memphis front is nine thousand nine hundred (9,900) feet. Besides the revetment at Memphis, two hundred thirty-one miles below Cairo, four thousand nine hundred (4,900) feet of spur dikes have been built.

Third District: This district includes the works of improvement at Lake Bolivar front, Ashbrook Neck, Greenville Harbor, Longwood, and Fitler Bend, Mississippi, Louisiana Bend, Lake Providence revetment and reach, Delta Point, and Reid-Bedford Bend, Louisiana: and at Redford, Arkansas, on the Arkansas River.

The work at Lake Bolivar front, four hundred seventeen miles below Cairo, consists of effective revetment three thousand one hundred fifty (3,150) feet long; the subaqueous mattress for seven hundred ninety-four (794) feet is of the old woven type and for about two thousand nine hundred sixty-eight (2,968) feet is of the old type reinforced by the fascine type. At Ashbrook Neck, four hundred forty-six miles below Cairo, ten thousand one hundred (10,100) feet of revetment have been built to prevent a cut-off which would have disturbed the regimen of the river for a long distance, above and below, and brought disaster to towns, levees, and other works along the river bank. One thousand feet of this is old work not reinforced, eight thousand six hundred (8,600) feet is reinforced with standard fascine mattress, and five hundred (500) feet is fascine mattress extension. The town and harbor of Greenville, four hundred seventy-eight miles below Cairo, are protected by a bank revetment having an effective length of twelve thousand five hundred (12,500) feet, of which one thousand seven hundred feet is of old type woven mattress, ten thousand seven hundred (10,700) feet is of the same type reinforced with fascine mattress, and four hundred feet is original fascine mattress. During the twelve years from 1882 to 1894, the bank at the Greenville Bend receded a distance of four thousand (4,000) feet. This work was begun in 1887 when ten submerged dikes were placed. The plan was changed to continuous revetment in 1891, and since the completion of the work it has been effective in maintaining the bank line. Repairs have been made from time to time. All exposed points which were subjected to scour have been rip-rapped. At Longwood, five hundred miles below Cairo, bank revetment has been placed in the rapidly caving bend to prevent the destruction of a large levee. The effective length of this revetment is four thousand two hundred (4,200) feet, all of the standard fascine type. The Lake Providence reach, five hundred seventeen to five hundred fifty-two miles below Cairo was selected by the Commission soon after its formation for improvement of low-water channel by means of contraction works and revetment of caving banks. Though marked deepening of shallow crossings resulted, the work was finally discontinued upon the introduction of dredging. Most of

the structures which were comparatively weak have been destroyed, but a much improved low-water channel still remains. The revetment in the Louisiana Bend five hundred twenty-two miles below Cairo, was originally part of the systematic improvement of Lake Providence reach. Work was begun in 1889 and was continued from time to time as funds were available until 1897. No extension or repair of this work has been made since then. The original work was fifteen thousand eight hundred twenty (15,820) feet long, of which about four thousand (4,000) feet at the lower end has been destroyed and more than half of the remaining eleven thousand eight hundred twenty (11,820) feet is covered by a bar at the upper end. The bank revetment at Lake Providence, five hundred forty miles below Cairo, protects the town and the important levee between the river and the lake. It has an effective length of twelve thousand six hundred (12,600) feet, of which one thousand two hundred (1,200) feet is reinforced old type woven mattress, one thousand seven hundred (1,700) feet is such type reinforced with fascine mattress, five thousand (5,000) feet is fascine mattress reinforced with fascine mattress, and four thousand seven hundred (4,700) feet is original fascine mattress. Many repairs have been made on this revetment since its construction. The work at Fitler Bend, five hundred fifty miles below Cairo, consists of two channel mats and seven connecting mats, protecting two thousand (2,000) feet of bank, the greater portion of which was graded and paved. Foot mats were also constructed along the entire work to make a proper connection between the upper bank and the subaqueous work. The object of the work at Delta Point, two hundred ninety-eight miles below Cairo, is to hold the point opposite Vicksburg and prevent further recession of the channel down stream away from the harbor, and thus aid in the improvement of Vicksburg Harbor. It has an effective length of five thousand nine hundred (5,900) feet, of which four thousand six hundred (4,600) feet is of woven mattress, six hundred (600) feet of such type reinforced with fascine mattress, and seven hundred (700) feet is of original fascine mattress. Reid-Bedford Bend, six hundred three miles below Cairo, was provided with a revetment to protect a long line of important levees from destruction. Mattresses covering two thousand (2,000) feet

of bank were placed in this bend, but owing to the high water no upper bank paving was possible. About six hundred feet of bank protection work have been placed at Red Fork, Arkansas River.

Fourth District: The works in this district include bank protection in Bondurant Chute and in Kempe Bend, improvement of harbors at Natchez and Vidalia, rectification of the Red and the Atchafalaya Rivers, and improvement of the harbor at New Orleans, Louisiana.

The work at Bondurant Chute, six hundred forty-four miles below Cairo, was undertaken in order to prevent the destruction of the levee lying between the upper end of Lake Bruen and the bank of the river. This levee was protected by means of mattresses constructed of lumber and willow brush, and a few experimental ones built entirely of lumber, for the submerged portion, with an upper bank pavement of concrete and rock. The revetment has a total length of three thousand four hundred forty (3,440) feet. The object of the work at Kempe Bend, six hundred fifty-eight miles below Cairo, has been to prevent further erosion of the bank line in the bend. The length of the revetment at this point is ten thousand eight hundred seventy-one (10,871) feet. Since the completion of the work two thousand three hundred (2,300) linear feet of connecting mattress was placed along the inshore edge of the channel mats, seven thousand two hundred (7,200) square feet of mattress was placed to repair breaks in the revetment, and four thousand (4,000) square feet of upper bank paving repaired. To prevent a threatened cut-off, which would destroy the harbors of Natchez by caving of banks, revetments were placed at places where needed. At Giles Bend twenty thousand three hundred twenty-eight (20,328) feet of subaqueous work, in two detached pieces of eight thousand one hundred ninety-two (8,192) feet and twelve thousand one hundred thirty-six (12,136) feet, respectively have been built. The unprotected interval between the pieces is about two thousand six hundred (2,600) feet. Repairs were made to the existing revetment by placing one hundred nine thousand eight hundred ninety (109,890) square feet of new mattress, and the upper bank was graded over an area of one hundred thirty-five thousand (135,000) square feet and paved for eighty-eight thousand seven hundred sixty-five (88,765) square feet.

On the Natchez front, the bank has been revetted with mattress three hundred feet wide for a length of two thousand five hundred fifty (2, 550) feet in two detached pieces of one thousand one hundred fifty (1,150) and one thousand four hundred (1,400) feet, respectively. The upper bank was graded for one thousand seven hundred ninety-four (1,794) linear feet and paved for nine hundred (900) linear feet. The unprotected interval between the two pieces of revetment is two thousand (2,000) feet long. At the junction of the Mississippi, Red, and Atchafalaya Rivers, seven hundred sixty-four miles below Cairo, the improvement consists in the maintenance of mattress sill dams in the Atchafalaya River for the purpose of preventing the enlargement of the stream, and dredging the low-water channel of the Old River for the purpose of maintaining an adequate depth between the Mississippi, Red and Atchafalaya Rivers. A channel one thousand two hundred fifty (1,250) feet long and averaging one hundred (100) feet wide at the bottom has been dredged through the bar at the Mississippi entrance to the Old River. The object of the work in New Orleans Harbor, nine hundred sixty-five miles below Cairo, is to prevent the erosion of the banks and consequent loss and damage to adjacent property. The work consists mainly of spur dikes placed at intervals of about four hundred fifty feet and of continuous revetment of the lower bank. In places where erosion was specially active, a continuous revetment was placed between the spurs. In Carrollton Bend, the banks are protected for seven thousand nine hundred thirty (7,930) feet by continuous mattress, and for the same distance five dikes in conjunction with the continuous mattress; in Greenville Bend, opposite Audubon Park, for one thousand nine hundred forty (1,940) feet by two spur dikes; and in the Gouldsboro-Algiers Bend for nine thousand four hundred seventy-five (9,475) feet by nineteen spur dikes; in the Third District reach for six thousand five hundred thirty-five feet by fourteen spur dikes, and for one thousand two hundred forty (1,240) feet by two spur dikes and a continuous mattress. A total of about five and one-half miles of bank is protected by dikes and continuous revetment in this locality.

DREDGING: Much dredging has been done by the Commission in the last few years. Sand bars which require dredging are found at frequent intervals between Cairo and the Red River.

In 1895 the Commission began in an experimental way to secure and maintain, below Cairo, a navigable channel by means of hydraulic dredging, working for a channel nine feet deep and two hundred fifty feet wide. The feasibility of maintaining a channel of the desired dimensions was established early. During the year of 1907, channels not less than ten feet in depth and of widths exceeding two hundred fifty feet were maintained through all the bars. Since that time much experimenting has been done as to the feasibility of a channel fourteen feet deep and five hundred feet wide.

Based upon the usual supposition that the width of each cut is the width of the section mouth of the dredge and that the side slopes of the Channel are 1 on 2 1/2, the amount of material moved by the dredges per year is as follows: 1,612,223 cubic yards in 1899; 1,145,558, in 1900; 1,666,465, in 1901; 813,380, in 1902; 891,098, in 1903; 2,149,734, in 1904; 197,847, in 1905; 297,300, in 1906; 1,151,739, in 1907; 6,167,766, in 1908; and 1,260,171, in 1909.

Consolidated Statement of all Appropriations Expended under the Mississippi River Commission to June 30, 1910.

Act of June 28, 1879 (organic)----------------------------	$ 175,000.00
Act of June 16, 1880 (sundry civil)----------------------------	150,000.00
Act of March 3, 1881 (river and harbor)----------------------	1,000,000.00
Act of March 3, 1881 (sundry civil)---------------------------	150,000.00
Act of August 2, 1882 (river and harbor)----------------------	4,123,000.00
Act of August 7, 1882 (sundry civil)-------------------------	150,000.00
Act of March 3, 1883 (sundry civil)---------------------------	150,000.00
Act of January 19, 1884(river and harbor)--------------------	1,000,000.00
Act of July 5, 1884 (river and harbor)-----------------------	75,000.00
Act of July 5, 1884 (river and harbor) less $5,000 transferred to snag-boat service------------------------	2,065,000.00
Act of July 7, 1884 (sundry civil)---------------------------	75,000.00

Act of August 5, 1886 (river and harbor), less $5,942.60 for expenses, office Chief of Engineers	$ 1,994,057.40
Act of August 5, 1886 (river and harbor), less $47.30 for expenses, office Chief of Engineers	29,952.70
Act of August 11, 1888 (river and harbor), less $4,859.00 for expenses, office Chief of Engineers	2,840,141.00
Act of August 11, 1888 (river and harbor)	75,000.00
Act of October 2, 1888 (sundry civil)	35,000.00
Act of October 19, 1888 (deficiency), less $4,214.39 reverted to the Treasury	20,785.61
Act of September 19, 1890 (river and harbor)	3,200,000.00
Act of September 30, 1890 (deficiency)	5,625.00
Act of March 3, 1891 (deficiency)	1,950.00
Act of March 3, 1891 (joint resolution)	1,000,000.00
Act of July 13, 1892 (river and harbor)	2,470,000.00
Act of July 28, 1892 (deficiency)	44.80
Act of March 3, 1893 (sundry civil)	2,665,000.00
Act of August 18, 1894 (river and harbor)	485,000.00
Act of August 18, 1894 (sundry civil)	2,665,000.00
Act of March 2, 1895 (sundry civil)	2,665,000.00
Act of June 3, 1896 (river and harbor)	909,000.00
Joint Resolution approved March 31, 1897	250,000.00
Act of June 4, 1897 (sundry civil)	2,933,333.00
Act of July 19, 1897 (deficiency)	625,000.00
Act of July 1, 1898 (sundry civil)	1,983,333.00
Act of March 3, 1899 (sundry civil)	2,583,333.00
Act of March 3, 1899 (river and harbor)	185,000.00
Act of June 6, 1890 (sundry civil), less $5,000.00 for expenses office Chief of Engineers	2,245,000.00
Act of June 13, 1902 (river and harbor)	2,200,000.00
Act of March 3, 1903 (sundry civil)	2,000,000.00
Act of April 28, 1904 (sundry civil)	2,000,000.00

Act of March 3, 1905 (river and harbor)------------------	$ 1,000,000.00
Act of March 3, 1905 (sundry civil)----------------------	2,000,000.00
Act of June 30, 1906 (sundry civil)----------------------	2,000,000.00
Act of March 2, 1907 (river and harbor)------------------	3,000,000.00
Act of May 27, 1908 (sundry civil)-----------------------	2,000,000.00
Act of March 4, 1909 (sundry civil) ---------------------	2,000,000.00
Act of June 25, 1910 (sundry civil)----------------------	2,000,000.00
Act of June 25, 1910 (river and harbor)------------------	2,000,000.00
Total Specific Appropriations	$ 63,179,555.51

CONCLUSION

A great amount of work has been done on the Mississippi River at a great expense. All told, the national government has expended on the main river and its branches between two hundred and two hundred fifty million dollars. Much of this sum has been spent in learning. Much of it has been wasted. Much of it remains, however, in permanently improved channels, and in public works ample for their task for a century.

As a result of the expenditure, there are now in the principal branches of the trunk system the following channels; in the lower Mississippi where all the work was done by the Mississippi River Commission, except the building of the jetties from the mouth to the Head of the Passes, from the mouth to the Red River (300 miles) ample water for the largest ocean steamship; from the Red River to Cairo, nine feet at all stages and usually ten; from Cairo to St. Louis, a portion which was added to the work of the Commission some time after it was formed, an uncertain channel nominally eight feet deep but sometimes reduced to five feet; from St. Louis to La Salle, one hundred miles from Chicago, six feet in the Mississippi and seven feet in the Illinois River; in the Upper Mississippi above the Illinois River, four and one-half feet to St. Paul, with usually five feet, and an incomplete five foot lock system to Minneapolis. In the Missouri, an uncertain and ill-kept channel practically abandoned by the engineers and traders, with usually three to four feet at summer stages as far as Kansas City; and in the Ohio, an un-

certain river, perhaps twenty inches to three feet at lowest water over the worst bars, with a heavy commerce in time of floods, and with its upper reaches being slowly improved to nine feet of depth by a system of locks and collapsible dams. All the latter part of this work has been done by Army Engineers, separate from what is known as the Mississippi River Commission.

It is a general opinion that the improvement of the channel, for the purpose of navigation, is not as important as the protection of the land from erosion by floods; and the improvement that has proven the most beneficial is that by the levees and by bank revetments. When the river is completely reveted, it will cover every bend into which the current sets, six hundred miles in all, between Cairo and New Orleans. When this is done it will not only provide a clear channel, but, in addition will give a safe bank for the farmers back of the river a safe foundation for levees, and will make land in the valley which is now worth $20.00 per acre, worth eight or ten times as much. It would be cheaper and far more practical to improve the river for the purpose of reclaiming the low lands along the river than to try to improve it for the purpose of navigation.

The feasibility of a fourteen foot channel has been declared too expensive and impracticable by the Mississippi River Commission. It has been decided by the engineers who compose the Commission that a nine foot channel is plenty deep enough for the present day river boats, and that, if a fourteen foot channel were constructed, neither lake steamers nor ocean vessels could travel through the river, hence it would mean the construction of a special type of vessel for river traffic alone, which is impracticable. A channel deep enough for ocean steamers would cost an immense amount of money, and since it has been found that the amount of transportation on the Mississippi is decreasing instead of increasing it is thought to be a waste of time and money to construct and maintain a deeper and wider channel than is possible with the dredges now in use.